The Flash Spectrum, Sumatra Eclipse, 1901 *May* 18.

By S. A. Mitchell, Ph.D.

(*Communicated by Professor J. K. Rees.*)

The transparency accompanying this paper contains:

1. Spectrum of the Second Flash.
2. Spectrum taken 5 seconds after Second Flash.

The spectra were photographed with an objective plane grating, and the positives made without enlargement.

The writer, through the courtesy of the former astronomical director of the Naval Observatory, Professor S. J. Brown, became a member of the expedition to view the Sumatra eclipse 1901 May 18.

Before reaching the island, it had been decided to occupy two stations for observations on the eclipse; one, Solok, near the central line of totality, the other Fort de Koch, near the northern edge of the Moon's shadow path.

On our arrival in the East Indies, it was soon found that the greatest trouble was going to be clouds, for almost at no time during the day was the sky perfectly clear. It was, therefore, thought best to subdivide the party at Solok, and a third station was selected at Sawah Loento, about twenty miles distant, at the terminus of the railroad, where were already Mr. and Mrs. Newall, of Cambridge, England, and a party from the Massachusetts Institute of Technology under the direction of Professor Burton.

Two instruments were taken to Sawah Loento, a camera of 104 inches focus to be used in connection with a cœlostat for photographing the corona; and a spectroscope consisting of a Rowland flat grating of 15,000 lines, with a ruled surface of $3\frac{1}{2}$ by 5 inches, and a quartz lens of $3\frac{23}{64}$ inch aperture and 72 inches focal length. Light from the Sun, reflected by the cœlostat mirror in a horizontal direction, fell on the grating, where it was diffracted and was brought to a focus on the photographic plate by means of the quartz lens. If grating and photographic plate are each perpendicular to the diffracted beam, the spectrum is "normal." It was arranged to photograph the first order spectrum from λ 3000 to λ 6000.

The final adjustments were made a few days before the eclipse by Mr. L. E. Jewell, the focusing being accomplished by means of a collimator designed by him.

The day of the eclipse dawned clear, and our hopes were that these favourable conditions would remain until after totality, which occurred shortly after noon. First contact was observed

in a perfectly cloudless sky, but soon after this clouds began to gather, and a quarter of an hour before second contact the sky was completely overcast.

The disappearing crescent of the Sun was watched by a binocular, before one half of which was arranged a small plane grating in such a way that with one eye the spectrum could be seen, with the other the Sun itself.

With this, shortly before the time of second contact, bright lines were seen for a few seconds at F and H, and in several places in the green and yellow, but these disappeared almost immediately, the Sun again being completely hidden by clouds—and the first flash passed without our being able to see it.

Towards the middle of totality conditions became a trifle better, so that it was possible to see, through clouds, the corona extending for about half a diameter from the Sun, and with the small spectroscope the "coronium line" quite distinctly. During no time of the $5^{m}\ 41^{s}$ of totality was an unclouded view of the corona obtained, but nevertheless the second flash was seen beautifully.

An hour after totality the clouds cleared away and a perfect sky remained for the rest of the afternoon!

Altogether eight exposures were made, one before and one just after totality for the cusp spectrum, one at first and one at second flash, and four with different lengths of exposure during the total phase. The first flash is entirely lacking, clouds having completely cut off all the light; the second flash seemed fully exposed, and it is to the discussion of its photograph that this paper is devoted.

The "Flash."—The peculiarities of this photograph of the flash are twofold:

1. Normal spectrum.
2. Great dispersion.

On the plate, the distance from F to H is 95·4 mm., and, as the spectrum is normal, 1 mm. therefore corresponds to a difference of wave-length of 9·37 tenth-metres, or 1 tenth-metre corresponds to a dispersion of about 0·1 mm. This is about one-fifth the dispersion obtained with the ordinary Rowland mounting with a $21\frac{1}{2}$-foot grating of 20,000 lines.

For some reason the spectra were not in perfect focus, and it was thus practically impossible to measure the cusp spectra. Owing to the great dispersion, although the bright lines of the flash were not perfectly sharp, measures were made and wave-lengths determined with a high degree of accuracy.

The plate was measured by one of the Repsold machines belonging to Columbia University, by comparing the spectrum lines directly with a millimetre scale. Measures with this machine can be made directly to 0·005 mm., and by estimation to 0·0005 mm., *i.e.* to 0·005 λ. However the sharpness of the lines did not permit them to be carried to this degree of accuracy

Comparisons with the Solar Spectrum.—Those who have

attempted to identify the bright lines with Rowland's map know the difficulties of this undertaking, which arise from the differences of dispersion between the solar spectrum and the flash, but more especially from the great differences of intensities of the lines in the two spectra. Great care was exercised in the determinations of the wave-lengths and in the comparisons with Rowland's tables of standard wave-lengths.

The spectrum extends from λ 4924 to λ 3320, but the focus becomes poor at the violet end beyond K, and measures were discontinued at λ 3835, Hη. The photograph from F to H was in the best focus, and for the present purposes considerations are confined to this region.

Neglecting H and He lines, 374 lines were measured in the flash between F and H; 91 of these were unidentified, 283 identified with lines in the solar spectrum. An arbitrary scale of intensities was assumed where 0 denotes a line seen with certainty, 10 the strongest line of the spectrum.

Two points are immediately noticed in comparing the two spectra; first, for each and every element, the brighter the solar line the brighter the flash line corresponding to it; second, the intensities of the solar lines which correspond to a line of given brightness in the flash differ with different metals. Fe and Ni lines of intensity 5, Ti, Sc, and V lines of intensity 2, are identified with flash lines of equal strength. These differences for the various elements were so marked that in order to arrive at their significance, and hence draw some conclusions regarding the 'reversing layer,' three tables were made. The first contains the flash lines arranged according to metals and intensities of lines (scale 0–10); the second the solar lines with which the flash lines were identified arranged according to metals and intensities (scale 1–1000); while the third was made up of all the lines in Rowland's map having an intensity greater than 2 (scale 1–1000).

Although we cannot directly compare the intensities of the bright lines of the flash (scale 0–10) with those of the dark lines given in Rowland's tables (scale 1–1000), we arrive at certain theoretical considerations if we compare the average intensities for the different elements, *i.e.* $\frac{\text{Flash intensities}}{\text{Solar intensities}}$, and also the ratios of the number of lines of each element identified in the flash to the whole number of solar lines for that metal. Forming these ratios, and arranging them, we are at once struck with the systematic variations not only in the ratios of intensities but also in the percentage of lines identified.

The meaning of these systematic differences will be understood if we consider these ratios in combination with the atomic weights of the various elements, as is done in Table I., where also are put down the number of the lines in the flash due to each metal.

TABLE I.

Group I.—Lines strong in flash, and in solar spectrum.

Element.	Atomic Weight.	Number of Lines Identified.	Intensity Flash / Intensity Solar Lines.	Number Lines Identified / Total Number Lines.
Na	23·0	—	—	—
Mg	24·3	1	0·10	1·00
Al	27·1	—	—	—
Ca	40·0	8	0·34	0·38
Group II.—Lines strong in flash, weak in solar spectrum.				
Sc	44·1	6	0·81	0·75
Ti	48·1	62	0·68	0·70
V	51·2	15	0·68	0·67
Cr	52·1	38	0·55	0·69
Mn	55·1	27	0·24	0·48
Sr	87·6	2	1 08	0·67
Y	88·7	2	0·50	0·67
Zr	90·6	9	0·46	0·70
Group III.—Lines weak in flash, strong in solar spectrum.				
Fe	56·0	125	0·23	0 32
Ni	58·7	9	0·36	0·28
Co	59·0	6	0 19	0 29

Looking at the numbers of the two last columns we see that the lines naturally fall into three groups as given in the table.

To these may also be added the following lines :

La, atomic weight 138·5, 3 lines at λ 4123·384, λ 4217·720, and λ 4613·544.

Ba, atomic weight 137, 1 line at λ 4554·211,

and the following lines possibly identified :

Si, atomic weight 12, 1 line at λ 3905·660,

Zn, atomic weight 65, 1 line at λ 4810·724,

Ce, atomic weight 92, 2 lines at λ 4003·912 and λ 4107·649.

In Group I. would also fall Al, if we consider the relative intensities of the two lines λ 3944·160 and λ 3971·674 ; and undoubtedly Na, if our plate took in the D lines.

The grouping of these lines is exactly that adopted by Evershed from his investigations of the Indian eclipse, except I have put Zr with Sr and V in Group II. Mn seems to represent the transition from Group II. to Group III.

As Evershed has pointed out, the remarkable variations of the relative intensities in the flash and Fraunhofer spectra are undoubtedly due to the heights to which the vapours of the different metals ascend in the chromosphere. We would natur-

ally expect that these heights vary according to the atomic weights of the metals, those of least atomic weights ascending to the greatest distances; and generally speaking this no doubt is true. But if we have two gases in the Sun's atmosphere, one a gas with an intrinsic brightness 1 and 100 miles in thickness, it would give a photographic line in the flash spectrum just as bright as the other gas of intrinsic brightness 100 and only 1 mile thick, *if* the Sun and Moon were relatively at rest during the period of the flash; but considering the gradual advance of the Moon in covering up successive layers of the Sun's atmosphere we see that in the emission spectrum the photographic brightness of the fainter gas would be many times that of the brighter. The absorption caused by a gas depends on the total number of molecules the solar ray comes in contact with, and will be very nearly equal in the two cases.

In view of these considerations it would therefore seem that the gases of the metals of Group II. extend very high, that they are nowhere very much condensed, and that practically all the gas contributes to the formation of the emission line, and hence, the flash lines are to be regarded as true reversals of the corresponding solar lines.

The vapours of Groups I. and III. are somewhat condensed near the Sun's surface (those of Group I., particularly Ca, reach far greater heights than those of Group III.), but as it is the upper portion that contributes most to the formation of the emission lines owing to the progressive motion of the Moon, the flash lines are to be regarded as only partial reversals of the Fraunhofer lines, the solar intensities being greater than the flash intensities.

Unknown Lines.—Taking account of lines in the flash identified with groups in the solar spectrum, about half the solar lines have corresponding lines in the flash. From the above considerations we see that it is highly improbable that lines of intensity 2 in the solar spectrum, and belonging to Groups I. and III., will have lines corresponding to them of sufficient brightness to show in this photograph of the flash. In fact, although there are 135 Fe lines of intensity 2 in Rowland's map between F and H, only 11 of these are found in the flash; and indeed great numbers of the feebler solar lines have no counterpart in the flash spectrum. But if, on the other hand, we compare the stronger lines, we see that every strong line of the solar spectrum almost without exception is found in the flash.

And so, remembering the meaning of the differences of intensity, we see no reason for giving up our faith in the existence of the "reversing layer."

Columbia University, New York City:
1902 *January* 28.

The Duration of Totality at Navalmoral.

By C. T. Whitmell, M.A., B.Sc.

For the total solar eclipse of 1900 May 28 I have shown, by a comparison of a large number of observations of the predicted and observed durations of totality for several localities, that the eclipse semidiameter of the Moon, adopted by the *British Nautical Almanac*, is too large. (See *Total Solar Eclipse of* 1900, pp. 75–81.) In the present paper I propose to give some details with regard to Navalmoral, whence I observed this eclipse.

For Navalmoral the following data were published by Dr. Downing :—

Adopted position, 5° 34′ W. longitude, 39° 52′ N. latitude.

		G.M.T. h m s
Eclipse begins	May 28	2 48 45
Totality "	"	4 6 12
Totality ends	"	4 7 39
Eclipse "	"	5 15 45

	Angle from N. Point. °
First contact	273
Second "	99
Third "	267
Fourth "	93

A note was appended to the effect that the predicted duration of totality (87^s) is perhaps 3^s too long.

The duration of totality at Navalmoral was carefully timed independently by four observers, and we agreed upon a totality of 80^s. Mr. Howarth, F.R.A.S., the Rev. S. J. Johnson, F.R.A.S., and Mr. Southall used only the eye unaided.

I observed with a low-power binocular, of which the right object-glass was fitted with a diffraction grating attached to a prism, so that the beginning and the ending of totality were estimated by the disappearance and the reappearance of the normal solar spectrum. The coincidence in the four estimates seems to afford reasonable ground for believing that the duration of totality was, as nearly as possible, 80^s.

There is thus a loss of at least 7^s to be accounted for, and this may be due to :—(*a*) errors in the lunar tables, (*b*) error in the adopted position of Navalmoral, (*c*) error in the *N.A.* value of the Moon's geocentric semidiameter, which for eclipses is 15′ 32″·65 at mean distance. It is assumed that the *N.A.* eclipse semidiameter of the Sun is correct.